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Datacast: the transmission system

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Summary

The BBC Datacast service allows one-way transmission of general data services for public service data broadcasting or for commercial purposes using the existing teletext system as the carrier. Such uses were anticipated when the 1976 UK teletext specification was written, so Datacast can co-exist with the normal teletext service (Ceefax) without problems. This Report provides a detailed specification of the Datacast transmission standard.

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DATACAST: THE TRANSMISSION SYSTEM

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1. INTRODUCTION

The specification of the UK teletext system[1] (now also known as CCIR system B teletext) was written over twelve years ago. Its prime purpose is to carry pages of text for display on a domestic television receiver. The system uses a fixed format in the interests of efficiency, reliability, ruggedness and low cost. There are now nearly thirty million receivers world-wide equipped for this system, operating in over thirty countries.

The specification allows for up to 16 lines per field to be used for teletext data, but there are practical limitations caused by the need for compatibility with existing receivers. The use of lines too early in the field interval can cause the data to be displayed on screen during the vertical flyback period on some receivers. Use of the later lines can cause a flared image at the top of the picture. In the UK about eight lines per field are currently used for teletext sevices but more are in use in some other countries.

Teletext was designed for receivers capable of storing only one page. Indeed, in 1974 it seemed doubtful whether manufacturers could afford to include even that single page of memory. So the teletext service repeats all pages (other than subtitles) frequently to allow users freely to choose and acquire fresh pages. This means that a resource capable of sending 55 000 pages per hour is currently used to send perhaps 300 different pages at any one time. Now that mass semiconductor storage is so cheap it is possible to think of databases being updated by teletext, so only new material is sent with occasional complete replenishments. Several additions to the UK teletext system have been made to assist the use of automated storage of multiple pages in a decoder. Each page carries a sixteen-bit cyclic redundancy check to allow correct and complete reception to be tested, and page subcodes are used to ensure that at any particular time all pages have unique addresses.

During 1985 the BBC was approached by several organisations interested in the possibility of using teletext data lines for carrying data for commercial purposes where a one-way one-to-many data link is appropriate. This Report describes the specification and operation of the Datacast system which was designed for this application. Experimental broadcasts began on September 10th, 1985. The BBC Datacast service was announced on October 3rd, 1985 and the first equipment built specifically to originate these signals was installed at BBC Television Centre on March 10th, 1986. In September 1986 the first users of Datacast were announced. There are now several major users of the service, including the London Stock Exchange and a chain of betting shops.

2. COMPATIBILITY

When the teletext specification was written in 1976, 75% of the address codes at the start of the data lines were allocated, but the other 25% were reserved for future use by requiring that the decoders initially produced should ignore them. This is the safest way to allow for expansion in a digital system. Later data services using different clock rates, modulation systems or framing codes would always be liable to interfere with existing systems, particularly if decoders are not designed with knowledge of all the possible future systems. Such problems may remain dormant for many years and then suddenly appear when particular combinations of data begin to be used. The only way to allow a teletext-like system, with an audience of millions, to develop safely is by reserving codes in the data channel and using them to introduce new services. Ideally these in turn still provide other reserved codes for further developments.

Now that so much decoder behaviour is under the control of numerous software writers in different organisations rather than a known few integrated circuit manufacturers it is becoming even more important that specifications are clear and unambiguous, and that everybody is working to the same document. It is also helpful if the broadcaster can provide test data to exercise reserved codes to assist the detailed checking of decoder functions. In the case of teletext we are finding that as new decoders appear there are more and more constraints we must put on the broadcast signal to avoid causing malfunctions in particular decoders. In retrospect it would have been preferable to define, perhaps by means of a flow diagram, the behaviour of a hypothetical reference decoder.

Most of the reserved codes referred to above have since been allocated to functions associated with the teletext pages, but 25% of that 25% were preserved throughout numerous discussions in national and international committees over the last twelve years for purposes unconnected with page-organised teletext. Some of these are the codes used for Datacast.

Fig. 1 classifies the various services currently

carried using teletext technology. It indicates the distinction between magazine/page-organised teletext and services using independent data-lines. These are two 'safe areas' on the diagram, outside which fall the other variations on the teletext format, such as changed framing codes or non-Hamming codes. In the outer ring of the diagram are systems using different data rates and/or different modulation systems.

mixed in any way in the transmission sequence, as the decoder should see each magazine as a separate data channel. This independence is only broken by the use of the serial magazine transmission mode which allows all incoming page headers, regardless of magazine, to be presented as they arrive and so puts an obligation on the broadcaster to maintain a meaningful sequence when all the page headers are taken together.

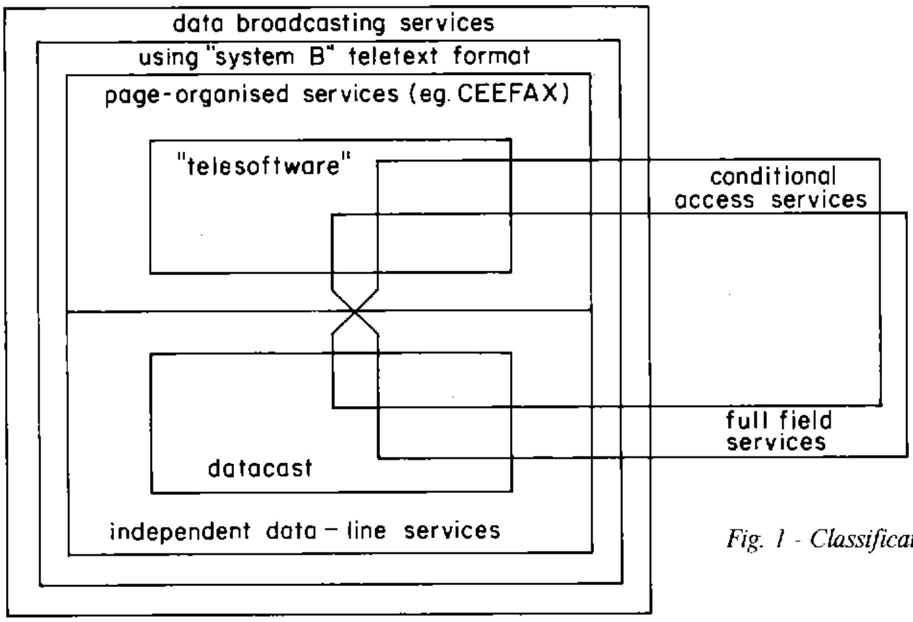

Fig. 1 - Classification of teletext services.

3. INDEPENDENT DATA-LINES

Each data-line in the teletext format starts with a clock run-in sequence (CRI) and framing code (FC). The next two eight-bit bytes, known as the magazine and row address group (MRAG), are Hamming-coded and each carries four message bits. In the page-organised teletext application these eight message bits are interpreted as a three-bit magazine number (in the range 1-8) and a five-bit row address (in the range 0-31).

The 1976 teletext specification requires that data-lines with row addresses in the range 24-31 be ignored. Subsequently it was decided that row addresses 24 and 25 represent an extension to the page, intended to be stored with the page and included in its cyclic redundancy check. Row addresses 26,27 and 28 are used, possibly more than once in each page, to carry additional information to over-write characters or to provide special display attributes.

All of these row addresses are still associated only with the current page of their particular magazine. Row address 0 (the page header) is used to define the boundaries between successive pages of a magazine.

The data-lines of different magazines can be

Row address 29 is reserved for applications where information relating to an entire magazine is being sent. Only row addresses 30 and 31 remain for applications unrelated to the page and magazine structure of teletext. Taken together with their eight 'magazine numbers' these provide 16 MRAG combinations which can serve as the addresses of 16 independent data channels. These can be used in any way at any time regardless of the content of the teletext service without interfering with the normal operation of a conventional teletext decoder operating according to the specification. This means that independent data-line traffic can be broadcast virtually immediately, without disrupting any magazine/page-organised teletext services being carried at the same time on the same network.

One of these addresses is used for the television service data-line[2] and four others are currently being used with BBC Datacast transmissions, although other formats of signal can also be used here without interfering with Datacast.

It is possible to depict the above allocation of magazine numbers and row addresses on a diagram with eight columns and 32 rows. Unfortunately this leads to confusion when it is pointed out, for example, that magazine 8, row 30 does not belong to any magazine neither is it row 30 of any page! An

alternative diagram is given in Fig. 2, where the 256 possible MRAGs are presented in terms of the contents of their first and second byte. It will be seen that the 16 combinations corresponding to the independent data-lines are selected by the first byte, the second byte having the fixed message bits **1111**. So a test of the second MRAG byte is sufficient to separate all the independent data-lines from those relating to a normal teletext service.

simplify both the generation and the reception of Datacast services in applications where several teletext-based services are multiplexed together onto a single video signal. It will be seen that the overheads have largely been arranged so that they are only incurred when they serve a function. It will also be apparent that the Datacast packet structure is directly applicable to other fixed-length packet systems, such as the sound/data multiplex of the MAC/packet family[3] based on 91-byte packets.

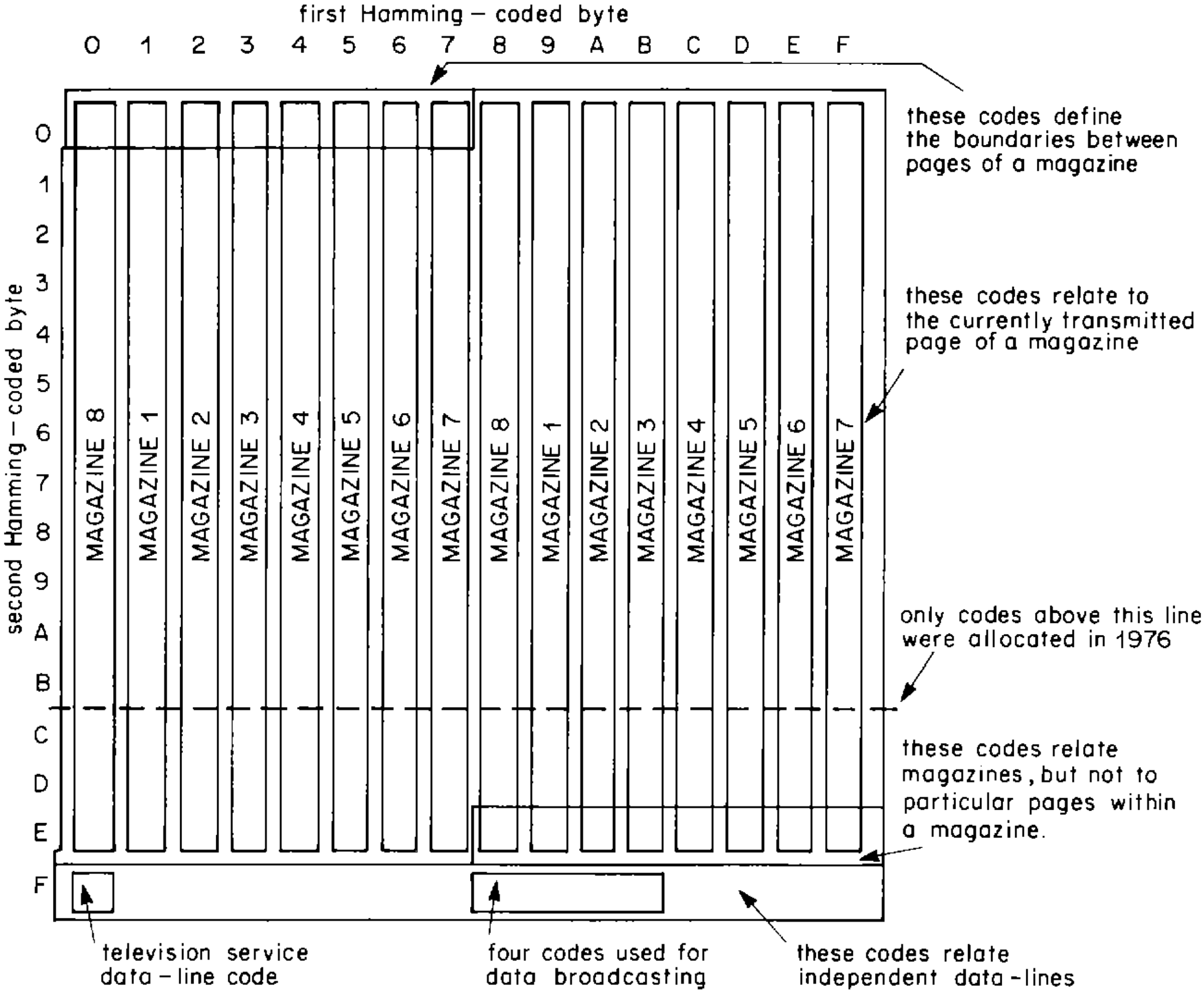

Fig. 2 - Interpretation of teletext magazine and row address group (MRAG).

4. DATACAST PACKET STRUCTURE

The self-contained nature of the Datacast data-line within the teletext multiplex makes it appropriate to refer to it as a Datacast packet.

The Datacast packet format is organised in eight-bit bytes as shown in Fig. 3, which emphasises how certain information in the early part of the packet influences the interpretation of the later part. Moreover, each packet stands alone and it can be interpreted without reference to others. Both these points, which are not generally true of page-organised teletext,

The function of the bytes of a Datacast packet are now considered in their order of transmission. This material should be read in conjuction with the UK teletext specification[1] where, for example, the Hamming code is defined.

4.1 Data channel group

The first byte of the MRAG of a Datacast packet identifies four possibilities. These can be used to distinguish between Datacast services arising at independent sources, such as regional contributions.

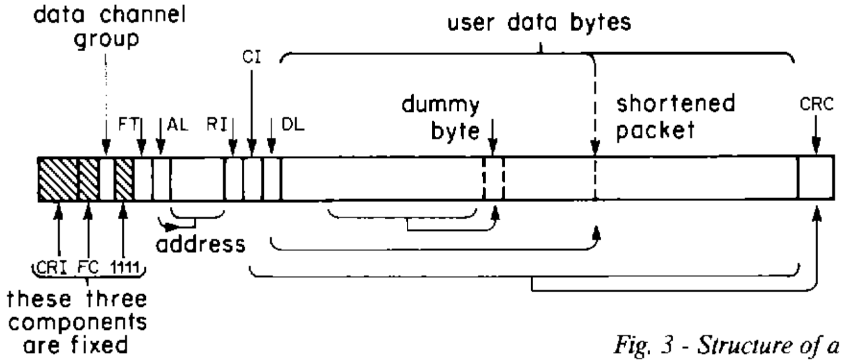

Fig. 3 - Structure of a Datacast data-line.

This makes it possible for the same addresses to be used by more than one source without contention, there is no need for overall control of address allocation.

The data channel group is analogous to the magazine number of conventional teletext; the same page numbers can be used in different magazines and they can be originated independently before combining onto a single video signal. Similarly, the data channel group number is a component of the complete information necessary uniquely to specify a Datacast service.

The second MRAG byte of a Datacast packet carries the Hamming-coded message bits **1111** indicating an independent data-line.

4.2 Format type byte (FT)

This Hamming-coded byte controls the interpretation of later bytes of the packet. The four message bits, in transmission order, are:

- **0** if Datacast format applies,
- **1** if the RI byte is used later,
- **1** if the CI byte is used later,
- **1** if the DL byte is used later.

If the first of these bits is set to **1** then the meaning of the other three is not defined, neither is the meaning of any subsequent data in that data-line. This allows new formats for use with independent data-lines to be defined without requiring the use of other data channel groups.

4.3 Packet address length (AL)

The first three message bits of this Hamming-coded byte indicate how many immediately following bytes are Hamming-coded and allocated to the packet address. The minimum is none, the maximum is six, giving a 24-bit address. The **111** state is reserved to extend the address capacity in a way not yet defined.

The last message bit is set to **0** when the access to, decoding and interpretation of this particular Datacast service is to be independent of and protected from interference by any other teletext-based services. This facility is provided in anticipation of some proposed uses where teletext and Datacast services may be used to control access to other services, including the extreme option of turning off the decoders.

4.4 Packet address bytes

Up to six Hamming-coded address bytes, as signalled by the AL byte, follow the AL byte. The least significant bytes are sent first. The least significant bits within each byte are sent first.

4.5 Packet repeat indicator byte (RI)

The RI byte is only present if signalled by the FT byte. Only then can the packet be repeated unchanged, noting that the RI byte itself does change.

The first four bits are set to **0** when a new packet is sent and this number is incremented modulo-16 on subsequent repeats of the identical packet. The next three bits are not yet defined. The last bit is set to **0** to indicate that no further repeats of that packet should be expected, but setting to **1** does not necessarily indicate that there will be a further repeat. This last bit is intended to assist certain decoder strategies.

4.6 Packet continuity indicator byte (CI)

The CI byte is only present if signalled by the FT byte. It is an eight-bit number incremented modulo-256 with each new packet of the same data channel group, address length and address bytes. It does not change during repeated transmission of the same packet.

If a CI byte is not signalled the eight-bit continuity indicator number is used to modify the CRC byte, so there is always a continuity indicator of one type or the other.

4.7 Data length byte (DL)

The DL byte is only present if signalled by the FT byte. The first six bits are a binary number

defining how many of the immediately following bytes (including dummy bytes) constitute data for delivery to the user. The last two bits are not yet defined. Note that the next most significant bit will need to be used if the Datacast format is applied to the 91-byte packets of the MAC/packet family of systems.

The DL byte is used when it is necessary to send an incompletely filled packet in order not to delay the transmission of data. Any remaining bytes before the CRC are not defined but are still subject to the CRC. A DL byte may be set to **0000 00XX** (in transmission order) to keep a data service open without sending data for delivery.

4.8 User data byte group

The remaining bytes in the packet, excepting the last two, and further limited by the DL byte when present, and excluding any dummy bytes, constitute the data carried for the users of that packet. There are generally between 28 and 36 user data bytes in a Datacast packet. There is no restriction on the coding of the user data bytes.

4.9 Byte transparency

Although there is no restriction on the coding of the user data bytes, it is, at present, necessary to eliminate long strings of **0**s and **1**s from the transmitted data to ensure that it is regenerated and decoded reliably. If within any user data byte group, taken together with any CI and DL bytes, a sequence of eight consecutive **0000 0000** bytes or a sequence of eight consecutive **1111 1111** bytes occurs the broadcaster will (except where there is no remaining byte in the user data byte group) insert a following dummy byte which forms part of the CRC but which is otherwise ignored by the decoder. The use of dummy bytes reduces the length of the user data byte group, but only in applications where complete bit-sequence independence is required in the user data. When the data is enciphered it is, in general, very unlikely that such sequences will occur.

The function described above may later be not required. It is therefore recommended that decoders be equipped with a simple method of disabling it at a later date.

4.10 Cyclic redundancy check (CRC)

The last two bytes of the Datacast packet are a sixteen-bit cyclic redundancy check on any CI and DL bytes and all bytes of the user data group, including dummy bytes. The data to be checked, with bits in transmission order is, in effect, applied to the circuit shown in Fig. 4, the register having previously been filled with **0**s. The gates are modulo-2 adders ('exclusive-OR'). When the feedback path is disabled the basic sixteen-bit CRC in transmission bit order is produced at the output.

It will be apparent that if the basic CRC is appended to the input data, the process will compare the calculated CRC with the incoming CRC and fill the register with sixteen **0**s. This indicates how real-time hardware can be used to check the CRC although it is currently more usual to conduct the operation in software.

When the CI bit is set, and an explicit continuity indicator is sent, the basic CRC is sent. When the CI bit is not set, the eight-bit continuity indication is sent by modifying the basic CRC. This modification is done at the sending end in such a way that the above comparison results in the register containing the eight-bit continuity indicator repeated twice, with the least significant bit at the right-hand end of the bytes in the register. A decoder can then extract the continuity indicator from the CRC and use a 'flywheel' technique to allow it to interpret the CRC correctly during occasional errors or even during packet loss.

This use of a sixteen-bit CRC in every Datacast packet assures, with high confidence, that any errors will be detected. The decoder will be able to indicate whether data is right, suspect or absent. The extent of the suspect or absent data can be indicated and, where packets are repeated, there is the possibility of recovering some of it.

Practical experience with Datacast transmissions shows that under normal conditions fewer than one received packet per million fails the CRC check. No corrupted packet has yet been seen to pass the CRC check.

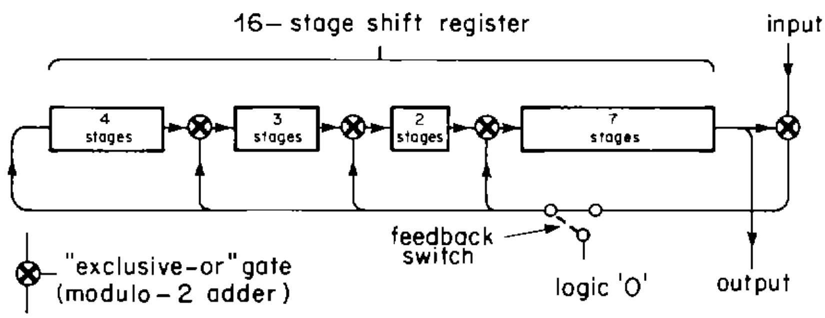

Fig. 4 - Generation and checking of cyclic redundancy check (CRC).

5. STANDARDISATION ASPECTS

In specifying the data broadcasting system described above account was taken of the agreed standards for data transmission and several features of conventional packet-based systems can be identified. However, certain contraints peculiar to the broadcasting application have also been recognised and these too have influenced the Datacast specification.

One of the advantages of a packet-based system is that individual packets can stand alone, they contain sufficient information to allow them to be checked and sent onward as required, possibly by more than one route, and at the receiver they can be checked and reassembled, if necessary, into the correct order. In the case of data carried in place of lines of the video waveform this advantage can only be enjoyed if each data-line corresponds to a complete packet, because individual data-lines are always liable to be inserted, deleted or even rearranged within a complex television network.

The familiar pattern of synchronisation of bits, bytes and packets, leading to a packet header containing address and control information, followed by a data field and terminated by a check word, can be seen. The particular way in which teletext-like data is multiplexed into the field-blanking interval of a television signal already provides very secure bit, byte and packet synchronisation. For reasons of compatibility and data security, as discussed in Section 2, these same mechanisms are used for Datacast. This also allows the integrated circuits already developed for the 'front end' of teletext reception to be used directly for Datacast. The selection between the standard page-organised teletext format and the independent data-line format is achieved immediately after byte synchronisation, as detailed in Section 3.

The useful length of the packets is very restricted. In the case of UK teletext on the 625/50 system the total of 45 bytes is reduced by:

bit synchronisation (two bytes),
byte synchronisation (one byte),
format selection (one byte),
channel group selection (one byte),
cyclic redundancy check (two bytes)

leaving only 38 bytes for address, control and the data itself.

In a conventional packet system certain address and control data fields are often unused, and the space wasted is not obvious as all subsequent data is simply delayed by a small amount. In the fixed-length short packet broadcast system a byte wasted is obviously a potential data-carrying byte lost for ever. The FT and AL bytes (see 4.2, 4.3) were introduced to allow redundant bytes to be eliminated. The implied continuity index option (see 4.10) was introduced to allow a further byte to be saved.

Most of these considerations apply equally well to the use of the 91-byte packets in the sound/data multiplex of the MAC/packet family[3] and it is clear that the Datacast format can be applied directly in this case.

6. DATACAST ORIGINATION EQUIPMENT

Datacast can be added to a video signal at a different point to teletext without any flow of information between the two although, of course, the same television line numbers in any one field-blanking interval cannot be used! Because there is sometimes a necessary redundancy in the normal teletext output, due to the need to repeat page headers to provide a page erasure interval, it would be more efficient to combine the two in a device that recognises this redundancy, but this makes the operation considerably more complex and more care would be needed to maintain reliability.

Fig. 5 shows a block diagram of a typical use of Datacast, indicating the broadcaster's area of responsibility. The Datacast transmission equipment is a single unit per network, with reserve available. The reserve is selected in such a way that data in course of transmission is not lost. The unit accepts inputs from six sources, usually via modems over leased lines. Source B is shown with conditional access equipment (encipherment, key distribution and decoder addressing) used before the signal is sent to the broadcaster and after it has been received. Source C comprises three sub-services, each with conditional access, which are combined before sending to the broadcaster along a single line. These sub-services may have different addresses or they may contain a sub-addressing facility within the data carried by a service using a single address.

The transmission equipment includes a unit for monitoring the input data, in particular it counts the number of user bytes and packets being sent against time of day together with measures of peak bit rate and delay through the system. Off-air reception can also usefully be analysed. This information is, of course, the raw material used in charging the users of the service. The Datacast transmission equipment developed by BBC Research Department is shown in Fig. 6 and may be manufactured under licence.

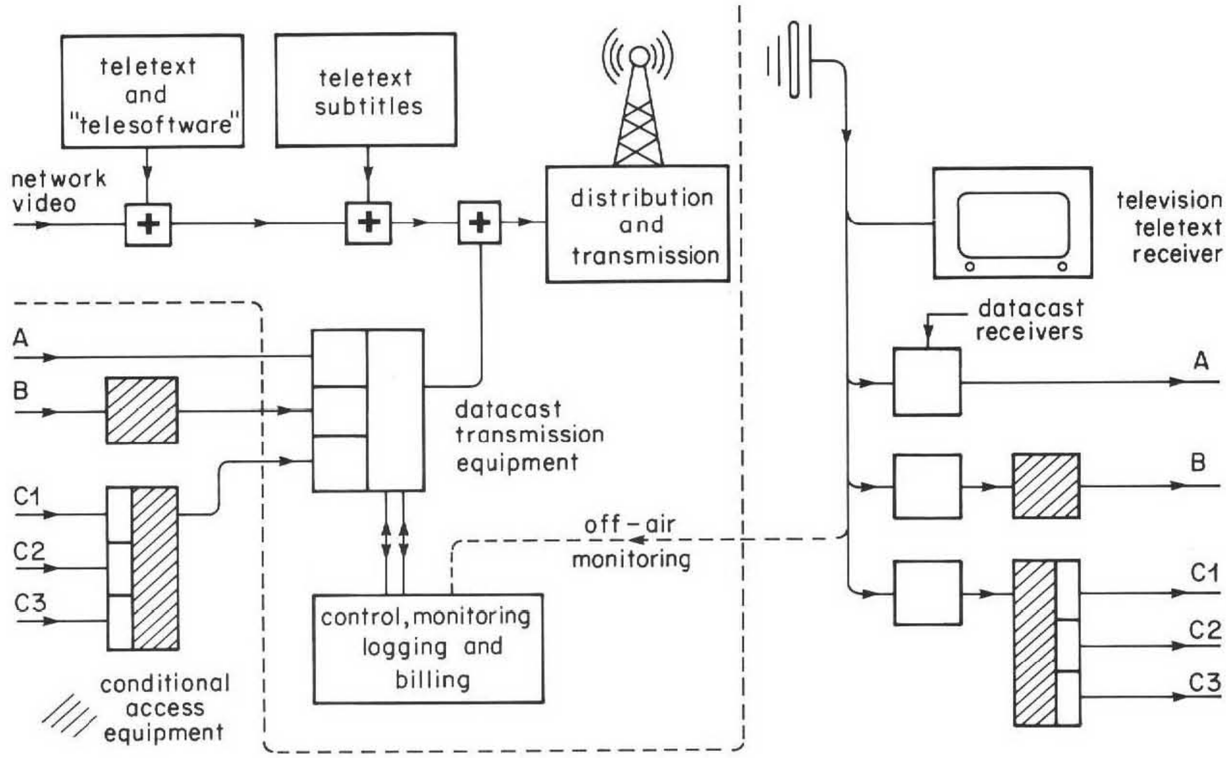

Fig. 5 - Typical Datacast broadcasting system.

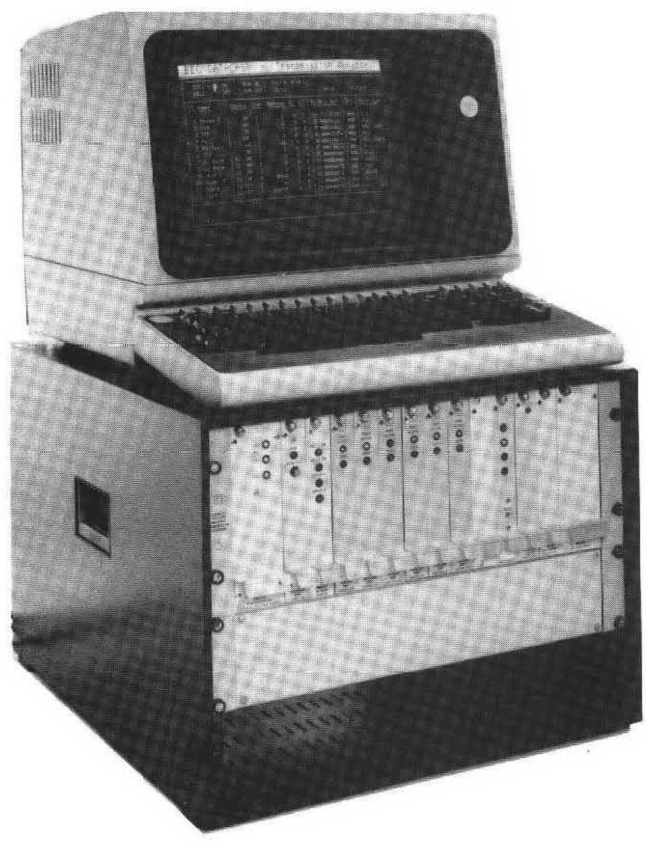

Fig. 6 - Datacast transmission equipment developed at BBC Research Department.

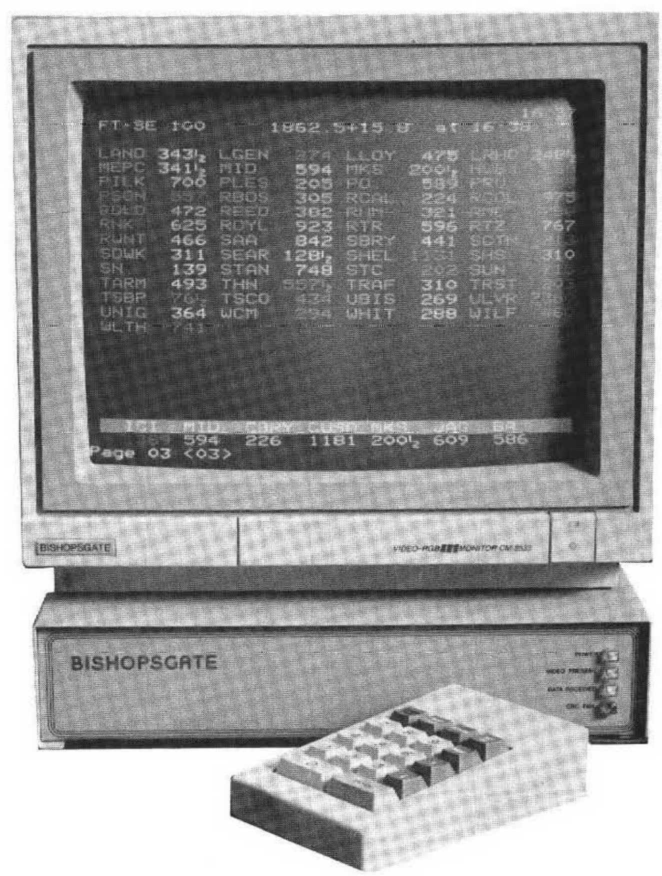

Fig. 7 - A commercially produced Datacast receiver.

7. DATACAST RECEPTION

Because the data transport mechanism is that of teletext, many of the existing teletext chips can be used directly or adapted for Datacast reception. The BBC Design and Equipment Department has produced a design which has been licensed to several manufacturers. A typical decoder is shown in Fig. 7. These units are, in effect, one-way modems. They have power and aerial input, and data output. The channel tuning and address are fixed and preselected within the unit.

Some manufacturers have combined the decoder with the interpretation and display circuitry for a particular user, producing a very compact unit. In one example the decoder contains a database and users can choose standard pages or compose their own pages from that data, which is continuously updated by Datacast. In another example a large LED screen displays share index information transmitted by Datacast.

8. DATA SECURITY

Although it is possible to imagine freely available services being broadcast by Datacast the majority of the applications are likely to be of a commercial nature where it will be necessary to prevent a casual user from understanding the message. Others may need to be secure against deliberate attack.

There are already techniques available for enciphering data over a one-way telecommunications link and any of these may be used on a Datacast channel. Methods of embedding individual codes within decoders in such a way that the decoders can be uniquely addressed, enabled, and disabled have been developed for Direct Broadcasting by Satellite and adapted for Datacast applications[4].

BBC Research Department has developed two particular sets of equipment for Datacast encipherment. One provides modest security, and rapid synchronisation, without needing any extra data signalling capacity. The source data is passed through a unit where each bit is modified by a function of the recent modified bits before onward transmission. That same function can be used to decipher the data in a complementary unit after the Datacast decoder. These operations are summarised in Fig. 8. There is a vast number of suitable functions available and the wrong functions will give a meaningless output. In effect, the function generator is the key to the operation, and the key may be changed by physically changing a component, or by entering details of the changed function by keyboard or card input. The weakness of this system is that anyone who has access to a deciphering unit can infer the key by examining the reponse to known input data. So, although it is secure against casual eavesdroppers, a planned attack will be successful. This method may be suitable where all decoders for a particular service are under the direct control of the service provider.

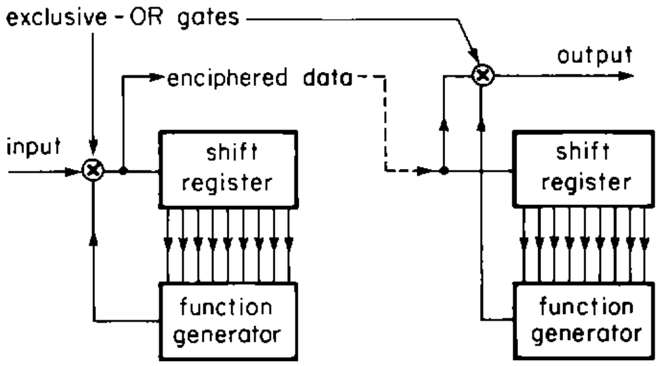

Fig. 8 - Simple encipherment and decipherment of serial data.

The second method uses data encipherment techniques according to draft International Standards based on a 64-bit block cipher. Because the use of the well-known and published US Data Encryption Standard (DES) is restricted an alternative block cipher, particularly suitable for software or VLSI implementation, has been devised at BBC Research Department. The keys are distributed to the decipherment units by various control messages inserted within the data stream. Each unit has a unique number embedded within it so messages can be addressed solely to one particular unit when necessary. Methods of sharing messages between units, and of sending intermediate keys controlling access to other keys, are provided in ways similar to those defined for Conditional Access television[3].

In equipment to demonstrate this second method the entire process is handled in a serial-in, serial-out unit based on a microprocessor. A short loading control program is held in read-only memory and the main decipherment and key management program, together with the unique identity of each unit, are loaded into non-volatile memory powered by a battery. This memory can be loaded in nine seconds and the information is held for several years. It is not possible to discover the contents of the memory from the input and output of the device. The demonstration device is shown in Fig. 9, with the cable used to intercept the data line. In a practical implementation this unit would be made 'tamper-proof' by, for example, potting it as a solid unit in which the battery supply to the memory would be interrupted during any attempt to cut it open. Clearly, the control of the

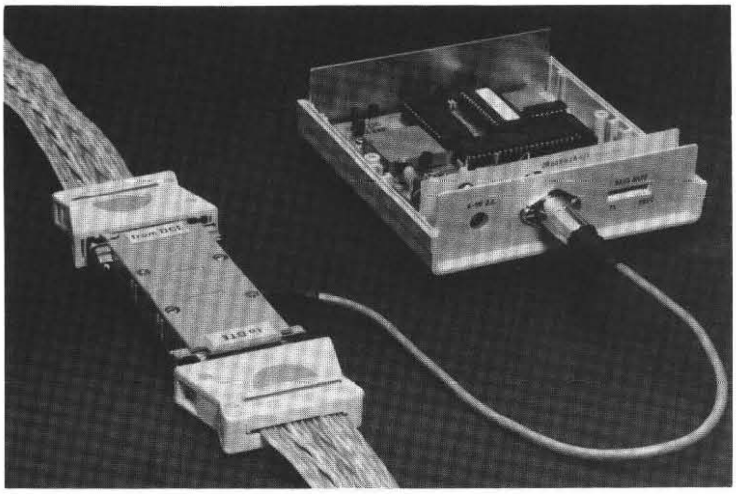

Fig. 9 - An 'in-line' Datacast decipherment unit.

software for loading such units is an important part of the security process but, as a virtually infinite number of variations of the encipherment algorithm are available, different versions can be supplied to different users.

This second method can be used to enable and disable individual decipherment units, or groups of them, by control messages sent as part of the data stream. Any of the proposed methods for implementing a 'pay-per-item' service can also be supported.

9. INTERNATIONAL USE

Already other broadcasters in Europe and elsewhere are planning to use the Datacast system for commercial data broadcasting. Organisations operating private video distribution systems, involving cable and satellite, are also showing interest. At present the BBC Datacast transmissions are being distributed, along with BBC television and teletext programmes, within several neighbouring countries by cable and to certain overseas cable companies by satellite.

Experiments have established that Datacast carried in the field-blanking interval travels well by satellite, as does conventional teletext. It can be converted to duobinary coding where necessary in the same way as teletext. As indicated above, data can alternatively be carried in the sound/data multiplex of the MAC/packet family by using the standard packet format.

It is important to identify which network is carrying the required data when many sources become available, and to specify the network as part of the packet address. The sixteen-bit network identification code which is carried, for example, in the television service data line[2] of BBC transmissions, serves this purpose. It corresponds to the code 'CHID' in the MAC/packet system. Such sixteen-bit codes, which are intended to be unique world-wide, have already been allocated for networks in the UK.

10. TARIFF POLICY

With such a unique resource it is important to exploit it in the best possible way as a public service. It would be very easy to sell the bulk of the capacity to a few users who could afford to pay for using the system inefficiently and thereby deny access to many small users whose modest needs cannot be met in any other way. The specification has been designed to support an almost unlimited number of individually addressable services and it is hoped that means will be provided for handling such uses without undue technical and administrative overheads. At the time of writing the charging structure for Datacast traffic is based on 3.8 UK pence per 1 000 bits.

11. FURTHER APPLICATIONS

The principles described above for carrying independent data lines by teletext for general applications can, of course, be used to provide more specific data services associated with the television and teletext programmes. In particular, there is growing UK interest in a 'programme delivery' service whereby suitably-equipped domestic video recorders can be pre-programmed to record particular programmes in their entirety even when they are not broadcast at a scheduled time. In the same way that 'packet 8/30' has already been allocated to carrying information about the television and teletext service, another of these independent data lines could be defined for use in a programme delivery service.

It is, however, important to preserve 'coding space' for future uses, in the same way as coding space

was reserved for Datacast nine years before it was needed. It is to be hoped that any systems similar to Datacast would use the same data channel groups as Datacast together with a different format indicator byte, rather than using more of the few remaining magazine and row address groups.

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